A Simulation Study of Daylighting Performance for Different Window Configurations in Architectural Design Studio to Enhance Lighting Quality at DUET, Gazipur

Farhana Ahsan
Assistant Professor, Department of Architecture, Dhaka University of Engineering and Technology (DUET), Gazipur - 1700, Bangladesh

ABSTRACT

Due to a lack of proper knowledge and awareness, the use of some blessings in nature is sometimes overlooked. Daylight is one of the blessings that is received almost free of cost from nature. Students in the design studios of DUET get excess daylight near the window, whereas those farther away do not. To control the glare, they use curtains and again lit the artificial lights to illuminate the entire space. The aim is to study the effectiveness of different window configurations in an architectural design studio to enhance daylighting quality. In the beginning, a 3D model of the studio will be generated in the ECOTECT to study the existing distribution and uniformity of daylight in the case space. Then, to enhance the quality and improve distribution, three alternative options will be generated with different sizes of window, light shelf, and reflector. These models will be exported to a physically-based backward raytracer, RADIANCE Synthetic Imaging software, for generating realistic lighting levels to validate and cross-check the ECOTECT results. Then, existing lighting conditions will be analyzed on some selected grid points. Hourly daylight data for the whole year will be generated at each point using the DAYSIM simulation exercise. It is expected that this paper will generate some ideas that will be beneficial for architects and designers to design windows for architectural design studios through simulation exercises to ensure a better daylighting environment.

Keywords
Daylighting performance ,Architectural design studio, Window configuration, Lightshelf, Simulation exercise

1. INTRODUCTION

In Bangladesh, very few studies have been done on the impact of daylight and student performance. As a result, the consideration of natural lighting quality in the classroom is less concern during designing an educational building. The environment of a classroom has a great impact on students. The lack of a good environment in the classroom can result in physiological and psychological impacts on the student. Each individual student in a classroom often does not get equal daylight on their desk [1]. In the design studio of DUET Gazipur, the quantity of interior daylight is not sufficient for drawing purposes. The students near the windows get much light than the ones sitting far from the windows. On the other hand, those who sit just beside the window most of the time get excess daylight, which creates glare problems [2]. As a result, they shut down the window and use artificial light. Eventually, the electricity bill raises unnecessarily, which gives a negative impact on the national energy consumption. As they work all day long in these studios, they get tired and stressed.

The objective of the study is to use daylight as the main source of light. Again, would try for distributing the illumination evenly to each student on their drifting table. In addition to get rid of glare would be a major concern. Eventually to make an economically beneficial condition by reducing the load of electricity. Overall, to create an enjoyable environment where a pupil can stay for a long period of time without stress and perform better.

This paper consists of three major parts. The importance of daylight, classroom environment, and standards are described in the first part. The second part intricate the steps of the research methodology. Finally, the findings of simulation results with a conclusion, presents the third part. It is expected that the examples of daylight simulation presented in this paper will be helpful to designers for understanding the significance of the simulation process for an effective day-lighted design studio.

2. LITERAURE

Human function depends on light since it enables us to view objects and carry out tasks. But it's also significant since it has an impact on people's physiology and psychology. Numerous studies have shown how important light is for enhancing mood, lowering weariness, increasing alertness, and regulating circadian rhythms [3].

2.1 Health and Wellbeing

From the studies of Boyce and colleagues it is clear that various lighting conditions have an impact on people's emotions [4]. Mood changes often affect changes in behaviour and performance at work. One of the characteristics of a high-performance building is the use of daylight or natural light for illumination. Natural light helps building inhabitants greatly on a physical and psychological level, in addition its advantages is the source of light is free [5]. The level of daylight important for the student's vision and it limits the effect of harmful electrical light [6]. The mental health of teachers and students is enhanced by daylight. Lighting influences mood and attitude according to Vetich [7].

2.2 Energy savings

Good daylighting can save electricity as long as electric lights are turned off or dimmed when natural light is adequate. Much of the institutions' energy budget is for lighting. This can be greatly reduced with well-designed natural light. Daylight can be related to economy as it gives some financial benefits [2]. There are various examples of economic advantages for the cost of natural light. A series of schools built in Johnston County, N.C., replaced artificial lights with natural light, which resulted in between 22% and 64% energy savings as compared to typical neighboring schools [8]. According to a report by the National Center for Education Statistics, 72% of the cost of energy in education buildings goes towards electricity, with the majority (56%) going toward lighting. Making a significant cut in electricity costs through daylighting can amount to substantial savings for other school expenses [9].

2.3 Learning space and daylight

The environment of a classroom has a great impact on students. Lack of proper environment of the classroom can result in physiological and psychological impacts on children. The most obvious effect of light on humans is in enabling vision and performance of visual tasks. The nature of the task as well as the amount, spectrum, and distribution of the light determines the level of performance that is achieved [4]. Performance on visual tasks gets better as light levels increase. A study by Santamaria and Bennett shows that, if the amount and distribution of light are controlled, most everyday visual tasks (such as reading and writing) can be performed better under daylight conditions rather than under artificial light sources (such as fluorescent light) [10]. Daylight is superior for tasks involving fine colour discrimination when it is provided at a high level without glare or any reduction in task visibility caused by veiling reflections or shadows [4].

2.4 Window and Glare

During midday, the sun hitting the ground can be more than 10,000 lux in tropical countries. For most people, the tolerable amount of sunlight while reading a book outside is around 40,000 lux. There is a large variation between the outside tolerable daylight from inside for reading. For a typical classroom, the amount of light tolerable for reading is around 500 lux. In some field studies, desktop illuminances of around 1500 lux to 2000 lux have been found to be too bright not because of the amount of illuminance but because of direct glare and glossy reflections. Care must be taken to avoid a large variation of brightness between surfaces at the far end of the room and those close to windows [11].

2.5 Window, Shading and Lightshelf

Window is the most common phenomena for daylight from the outdoor space. To control the amount of light penetration, window size can act as an important parameter. With a larger window a great extent of natural light can enter into the interior space. To decrease the quantity of illumination window size can be reduced.
Architectural shading solutions are typically part of the exterior facade. Lightshelves, overhangs, fins, shade screens, venetian blinds, vertical blinds, are commonly used shading systems. One drawback of using shading device is the risk of reduced daylight level [12]. The design of effective shading devices will depend on the solar orientation of a particular building facade. For example, in the summer when sun angles are simple fixed overhangs are very effective at shading south-facing windows (Figure 01). However, during the summer's peak heat gain periods, the same horizontal device is unsuccessful at preventing low afternoon light from entering windows facing west. [13].

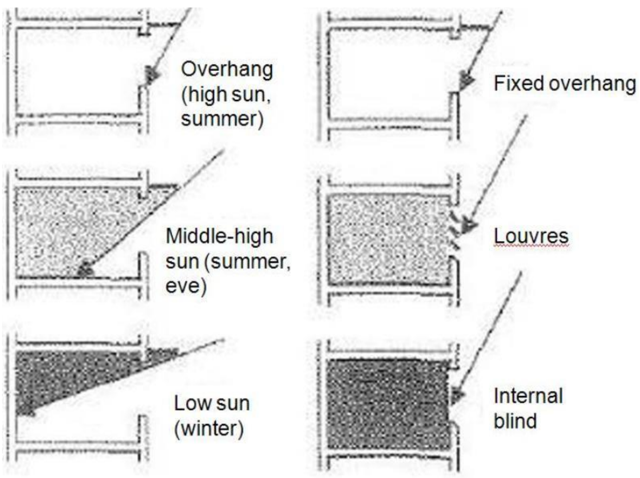


Fig. 01: Different types of shading solutions (cited from Don Prowler, 2014)

One of the effective forms of shading device is the lightshelf. A lightshelf is a horizontal surface that reflects daylight deep into a building. Lightshelves with high-reflectance upper surfaces are positioned above eye level to reflect sunshine onto the ceiling and farther into the room [14]. At the same time, the lightshelf shades the lower part of any window, reducing the amount of light near the window, which normally has much higher illumination than the deeper parts of spaces and projects the light towards the back (Figure 02). The result is balanced luminous environment with less contrast and glare [14].

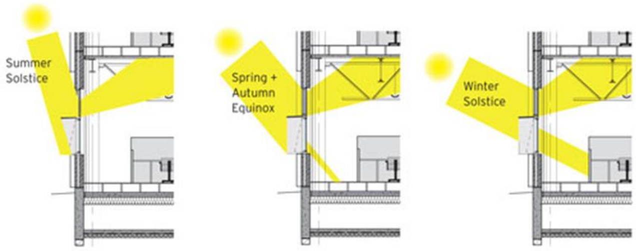


Fig. 02: Light shelves (cited from A.G.S. 2000)

2.6 Illumination standards

Bangladesh National Building Code 2006 (BNBC) follows a set of minimum recommended illuminance levels for a variety of visual tasks and space functions for educational buildings [15]. The guidelines for consideration of the brightness ratio in classrooms are illustrated in table I.

Table I: Recommended values of illumination for Educational Building (BNBC, 2006).

Area of Activity	Illumination [Lux]
Class and Lecture Rooms	
Desks	300
Black boards	250
Art Rooms	400
Assembly Halls Examination	300

Whereas the International Standard ISO measured the level in Reading area: 500 Lux and in Art rooms: 750 Lux [16].
The European norm provides guidelines for illuminations need for all different types' activities at school buildings are illustrated in table II [17].

Table II: Overview of tasks in a classroom together with the requirements for the luminance by European norm.

The Teacher	The Student	Standard Illuminance	
		In the class	In general
Writing on blackboard	Reading on blackboard	500 lux (vertical)	200 lux
Talking to students	Paying attention to the teacher	300 lux	300 lux
Showing presentations (slide, PowerPoints, television program, etc.)	Looking at the screen	300/10 lux	10 lux
Paying attention to working students	Writing, reading, drawing, etc.	300 lux	300 lux
Coaching computer activities	Looking to the computer screen and the paper	50 lux	300 lux above the computer
Preparing lessons	Not present	300 lux	50 lux

3. METHODOLOGY

The study has been completed in three stages; physical survey, simulation study and analysis. The study building is selected in Gazipur Duet campus (Figure 03, 04), which is an academic building.
In first stage the building (Figure 05) and the study area is surveyed physically. The physical and environmental characteristics like as building type, building heights, orientation and the surrounding condition are observed. Then one room that is a design studio (Figure 06) is selected. Here again the interior space, window type, orientation, glazing characteristics, surface area and materials are inspected.

Fig. 03: Google map view of DUET campus

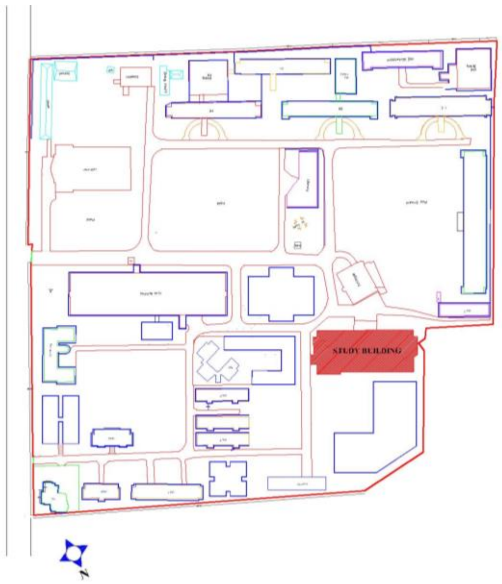


Fig. 04: Master plan of DUET campus

Fig. 05: South facade of the study building

In second stage a 3D model is generated in computer software for simulation. Four types of window configurations are studied in three software's ECOTECT, RADIANCE and DAYSIM.

The analysis is done in the third stage for finding a better design decision.

Fig. 06: Interior of the study design studio

3.1 Simulation Study

The amount of daylight penetration can be calculated by computer simulation study before construction. The parameters can be changed and with different design solution the suitable option can be identified with the help of the computer software. Again, the study can be performed in different climatic condition, date, time etc. Three computer version simulation programs are used in the study for four different window configurations to take the best option. Firstly, the ECOTECT v5.5 is used which a comprehensive building analysis software. It is a highly visual, architectural and analysis tool with lighting thermal, energy, shading and acoustic performance analysis functions [18], [19]. Then RADIANCE 3p7 is used which is more focused and accurate daylighting simulation tool [20]. Lastly DAYSIM 2.1.p4 simulation program based on the concept of dynamic annual daylight performance metrics is used [21].

3.2 Simulation Parameters

The quantitative and qualitative assessments of the design strategies the following parameters are considered:

Location	Dhaka, Bangladesh. (90.4° E. 23.8° N) *
Time	15 April
Calculation Settings	Full Daylight Analysis
Precision	High
Local Terrain	Urban
Window (dirt on glass)	Average
Sky Illumination Model	CIE Overcast
Design Sky Illuminance	16,500 Lux [21].

NB: Though the actual location of the study building is in Gazipur, it is similar and convenient to take the location as Dhaka.

3.3 Study Space

The study building is twelve storey high. The surrounding is mostly open, but there is a six-storey building on the south east corner. As the study space (marked on Figure 05) is on south west side, there is no barrier to entering light into the studio from outdoor area. The study zone is the design studio on the third floor (Fig. 07). The parameters of the study are as follows.

Total floor area	**17,851 sft**
The study area	1867 sft
Clear height of the design studio	12 ft
Work Plane height	3 ft

The parameters (Table I) of the internal finish materials are found by the field survey are used in the modelling.

Table I: Parameters of the internal finish materials

Model	Material	Reflectance
Ceiling/Roof	White painted plaster	0.7
Internal wall	white painted brick work	0.7
Floor	White cc finishes	0.5
Glazing	Single pane of glass with aluminium frame	0.92 U value 6W/m^{2}K

3.4 Performance Evaluation Process

The total design studio is divided into grids (Figure 08) for the purpose of simulation. Then 275 points in the open studio are found to generate of daylight levels at 3 ft above floor level which represent the table top of drafting tables. Each intersection point of the grid was coded according to the number-letter system shown in Figure 08. Total 275 simulated illumination values are generated by ECOTECT. These values are plotted into tables (Tables III, IV, V and VI), with the codes coinciding with intersection of letters (rows) and numbers (columns) and then compared for the different situations. One axes XX' (Figure 08), were created across the plan, to assess the fluctuation of daylight levels, from the window towards the opposite wall of the space [12].

Fig. 7: Study floor plan of NAB building

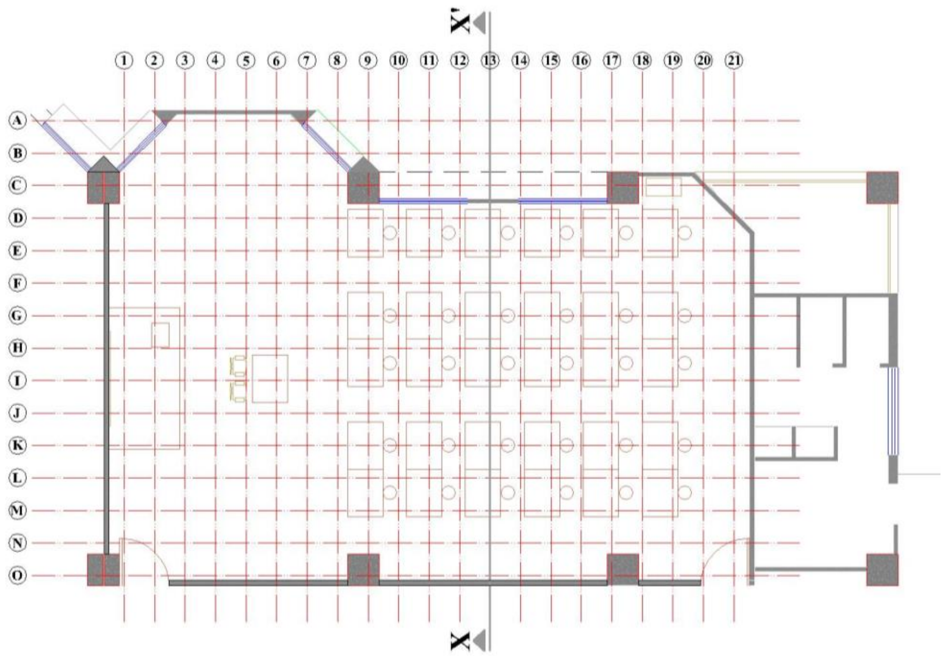
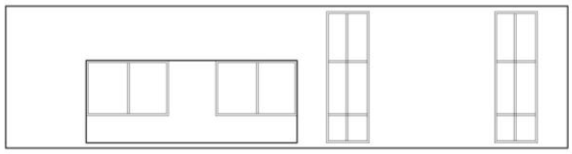
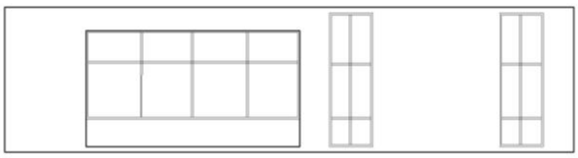
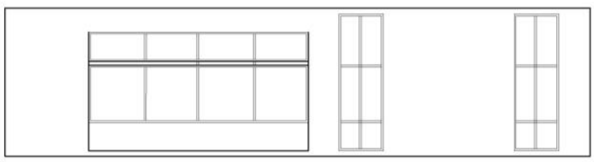
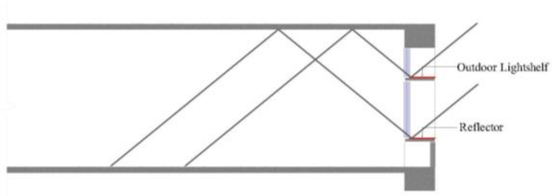
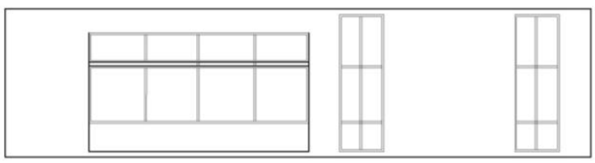
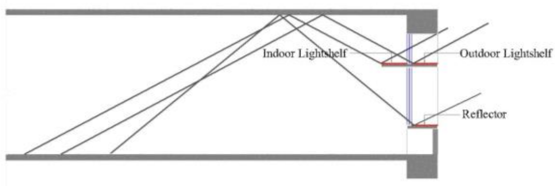


Fig. 08: Plan showing the grid with node references

The whole simulation study is done in four types of window configuration one by one with different design parameters (Table II). The types are as follows-
Case A: The simulation study done in the existing situation. There are four windows on the south exterior wall (Figure 05, 08) of the studio.
Case B: In this case the window has been widen through wall and the height is increased to roof level.
Case C: Shading device and light shelve are added on the seal and lintel level outside of the wall in case C.
Case D: Another light shelve is implemented on the lintel level in inner side of the studio.

Table II: Window design parameters for the study

Case	Elevation	Section
A		
B		
C		
D		

For each cases the 3D model is generated for computer simulation in ECOTECT program to calculate the amount of daylight on each grid point on the work-plane. The models were then exported to Radiance Synthetic Imaging software for generating realistic predictions of lighting levels. An additional imaginary horizontal plane above 3ft from the floor level is created to show daylight contour map on work plane height, for Dextop RADIANCE. Finally, a performance metrics was done with DAYSIM to get a complete annual picture [12].

4. RESULT AND ANALYSIS

4.1 Evaluation criteria

The findings of the computer simulation were evaluated based on the following criteria [12].

a. Average daylight levels and daylight factors on the drafting table height.
b. Number of points within acceptable illumination levels.
c. Fluctuation of daylight levels from the window towards deeper parts of the studio.
d. Comparison of rendered images of the example studio generated by RADIANCE for luminance levels on specific surface.
e. Different performance metrics with DAYSIM to verify the compliance of the decisions with annual performance.

4.2 Average daylight levels and daylight factors

From the Figure 09 it can be seen that how the daylight factor changes in different cases. In Case A when the window was small the illuminance entered through the window could not cover the whole area but it changed to a great extent while the window size is expanded in Case B. But glare is very high near the window. In next two Cases the glare is reduced by using light shelve without dropping the illuminance.

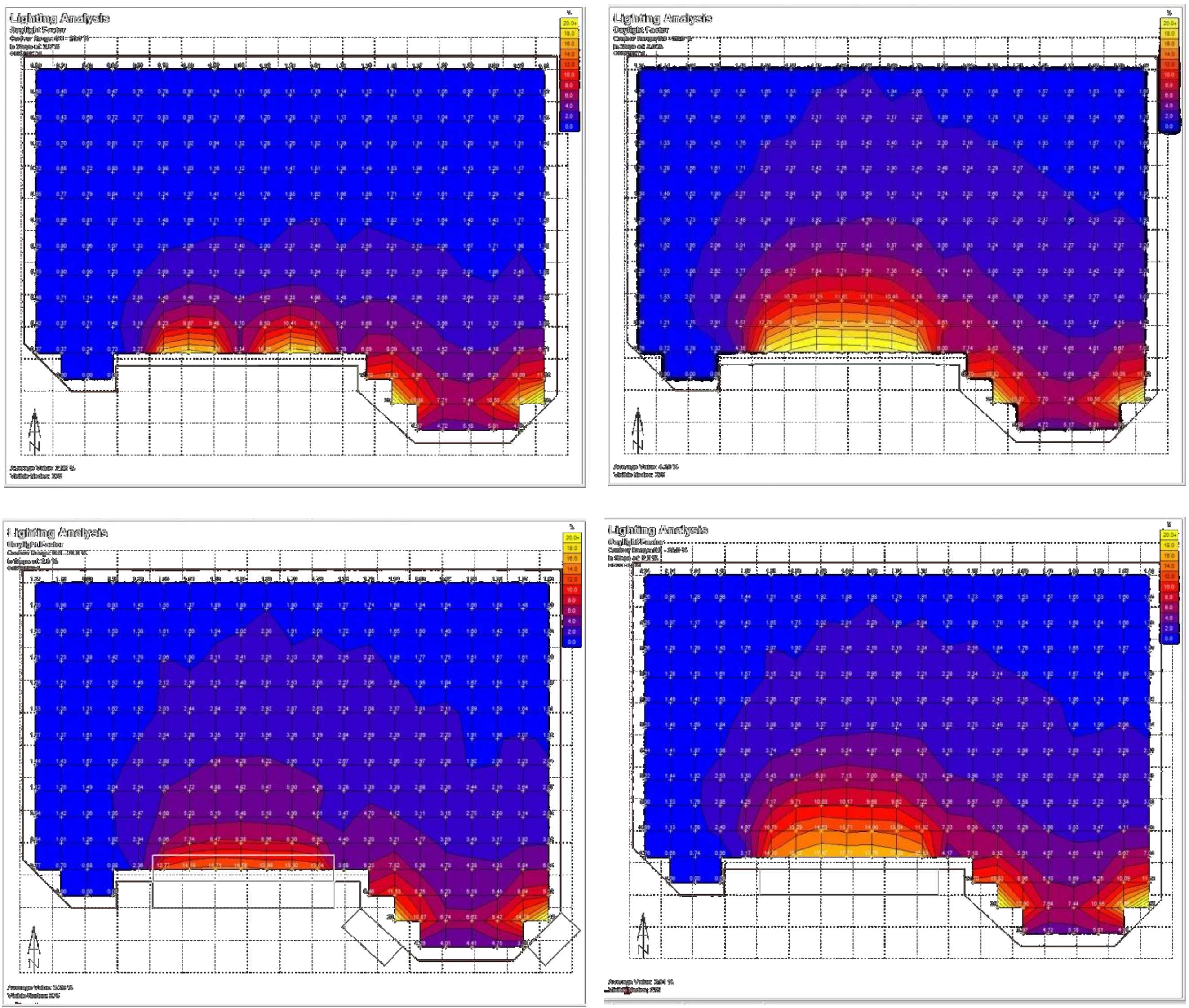
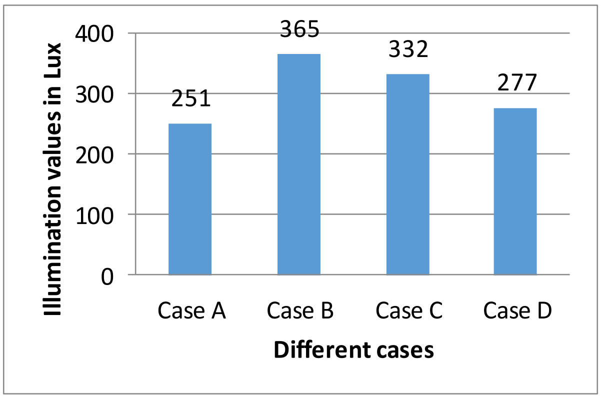


Fig. 09: Daylight factors on node points in different cases A, B, C and D (clockwise)

The following bar diagram (figure 10) explains that average daylight level (250 Lux) is very low in existing situation (Case A). It increased in Case B then again fall down in following two cases but the difference between two points is lessen. Same things happen in daylight factors, first grow high and then declined. The standard illumination for drawing purpose in BNBC is 400 Lux. In existing situation only, the tables near the window get this amount of daylight. On the last Case though, the average value is not increased very high but the distribution is better. These is found very clearly from the Table III, IV, V and VI.



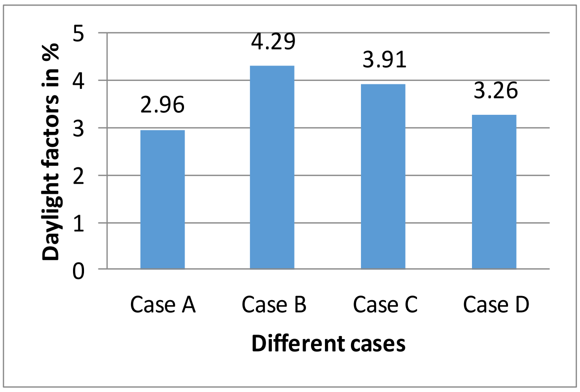


Fig. 10: a) Average daylight levels and b) Average daylight factor

4.3 Comparison of illumination levels

Comparing the four conditions from the Table III, IV, V.VI we found that, in Case A of existing condition only 46 node points get the illumination level higher than 300 lux, which is the recommended level mentioned in Bangladesh National Building Code, 2006 for class room [13]. It is 16.7% of total 275 number nodes. In this case glare is very limited, only 13 points get more than 900 Lux will create glare, as these levels exceed three times the recommended values [22], [23]. In Case B when the window changed to a large one, the number of points over get illumination over 300 Lux increases to 66 points (24%) but glare points increase also high. It increases to 26 points which is 9.4%. Then in Case D the external light shelf added the situation turned better. Glare points (over 900 Lux) decreased to some extent, 21 points (7.6%) and 67 node points (24.3%) get light more than 300 Lux. In last stage, Case D, the glare points decreased very low, only 11 points (4%) and 57 points (20.7%) get more than 300 Lux. So, in Case D the situation is more preferable as the overall distribution of light is even though the average illumination is low. The summery can be seen from the Table VII.

Table III: Daylight distribution on nodes for Case A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A		424	494	441	401	508															
B	2473	1525	899	632	655	1112	2146														
C	988	857	531	484	519	762	1133	1079													
D	570	540	355	345	385	470	688	586	449	1589	1668	1296	**453**	1522	1624	1478	278	61	20	31	31
E	328	323	265	265	302	403	439	483	465	741	885	722	**484**	806	839	699	270	126	60	32	36
F	226	251	198	225	217	251	345	347	296	424	453	393	**361**	449	464	374	217	122	97	61	41
G	153	209	158	171	172	186	234	248	239	284	272	276	**220**	265	287	228	163	105	76	68	64
H	151	168	145	142	175	180	188	217	172	204	201	170	**204**	197	175	171	113	91	81	68	64
I	126	150	122	119	139	131	155	165	154	180	169	139	**137**	146	144	126	113	91	69	73	61
J	135	124	110	112	137	125	145	135	141	138	157	149	**121**	120	116	105	98	71	68	65	56
K	120	99	102	96	126	133	130	126	116	128	125	137	**95**	99	88	83	76	68	61	55	61
L	105	111	99	102	113	114	115	114	118	113	107	109	**112**	80	87	78	65	69	54	59	61
M	90	104	94	99	88	96	100	107	96	111	108	102	**90**	103	79	71	66	61	59	37	60
N	86	95	91	82	90	97	95	95	97	101	94	92	**94**	97	78	66	64	40	61	34	58
O	93	96	92	105	91	99	101	98	105	86	106	95	**92**	48	68	65	63	70	36	63	59
Total number of node points = **275**																					
Number of points 300~900 Lux = **46**																					
Number of glare points (>900 Lux) = **13**																					

Table IV: Daylight distribution on nodes for Case B

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
A		424	494	440	401	508															
B	2428	1525	897	632	954	1111	2146														
C	988	857	531	484	519	762	1133	1080													
D	597	567	408	395	423	505	724	658	510	1820	1942	2000	**2031**	2030	1921	1670	370	112	66	61	65
E	359	352	295	300	344	468	513	587	733	1163	1395	1443	**1448**	1497	1338	1087	474	247	148	103	80
F	257	289	235	252	281	323	412	509	507	695	888	944	**988**	948	914	678	415	262	171	130	92
G	197	243	205	238	228	255	323	375	403	545	626	673	**655**	667	571	497	321	222	160	130	109
H	189	201	188	193	216	262	276	334	303	423	456	461	**490**	470	390	335	255	175	166	130	122
I	164	189	181	166	202	200	214	256	275	331	346	354	**338**	333	329	284	211	168	147	135	106
J	157	158	148	173	188	183	221	197	233	267	295	306	**259**	279	247	217	193	153	129	127	110
K	162	161	139	157	168	185	194	199	211	204	246	273	**235**	206	202	198	146	137	132	109	106
L	141	144	142	140	164	163	171	183	196	199	204	206	**224**	189	179	176	149	121	118	113	107
M	149	141	131	142	129	145	151	166	161	188	185	195	**171**	185	161	141	132	123	109	82	106
N	140	136	130	140	133	142	142	147	149	177	165	182	**173**	176	130	140	134	91	109	81	107
O	129	139	132	151	131	146	150	156	152	148	160	170	**165**	125	132	129	126	112	89	97	106
Total number of node points = **275**																					
Number of points 300~900 Lux = **66**																					
Number of glare points (>900 Lux) =**26**																					

Table V: Daylight distribution on nodes for Case C

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
A		424	494	441	401	508															
B	2428	1525	897	632	649	1096	2140														
C	988	857	531	484	519	762	1133	1080													
D	597	567	409	395	423	502	708	611	354	1411	1448	1509	**1511**	1485	1421	1250	269	82	63	59	65
E	359	350	295	300	338	450	484	542	623	962	1151	1190	**1165**	1244	1130	915	422	204	134	96	75
F	255	284	231	248	277	304	397	482	456	614	818	822	**864**	852	825	609	361	242	150	130	85
G	197	239	192	220	222	248	308	338	364	487	560	595	**606**	579	519	461	280	215	155	122	103
H	179	194	188	177	216	253	253	307	268	389	412	414	**446**	422	356	318	243	169	159	120	122
I	164	175	167	166	186	190	212	234	256	304	318	329	**306**	304	302	261	194	156	143	119	106
J	156	158	148	158	182	183	206	177	212	243	271	282	**238**	250	227	200	172	138	120	127	110
K	162	161	139	142	155	170	182	199	194	188	226	250	**221**	188	185	183	133	137	130	109	103
L	130	133	142	140	164	150	157	183	178	199	186	186	**209**	189	163	176	149	121	118	102	107
M	149	141	131	142	129	131	151	153	145	174	169	195	**171**	172	148	141	121	123	100	82	106
N	140	136	130	140	133	130	142	147	149	163	153	169	**160**	163	120	128	122	84	109	81	107
O	119	139	132	139	120	135	139	145	139	148	148	156	**153**	117	132	129	116	101	89	97	106
Total number of node points = **275**																					
Number of points 300~900 Lux = **67**																					
Number of glare points (>900 Lux) =**21**																					

Table VI: Daylight distribion on nodes for Case D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A		288	404	375	341	365															
B	2076	1253	800	563	573	924	1776														
C	792	752	463	442	444	701	980	804													
D	514	496	368	373	399	457	640	530	313	1151	1183	1189	**1239**	1250	1206	1085	200	75	58	60	65
E	325	325	270	297	305	405	442	442	374	588	705	711	**712**	720	658	515	250	155	107	86	72
F	240	267	212	233	268	264	350	399	295	341	425	440	**466**	441	444	398	210	165	116	121	80
G	176	224	183	207	201	228	288	288	279	362	425	465	**410**	415	401	346	216	174	126	106	95
H	174	190	170	163	202	252	243	280	227	316	356	358	**363**	369	303	245	224	130	142	121	122
I	163	176	168	162	187	178	203	220	242	271	286	303	**286**	285	279	216	170	142	137	116	108
J	154	140	134	161	180	171	202	176	191	224	244	248	**218**	241	207	173	163	138	112	115	113
K	159	162	132	142	156	165	174	175	193	174	215	239	**204**	181	184	181	127	129	133	103	106
L	134	137	134	128	149	150	156	189	182	183	181	192	**205**	179	162	176	145	120	117	105	102
M	153	133	121	136	127	136	140	158	146	171	162	195	**172**	165	144	137	117	127	103	85	109
N	130	125	134	141	131	131	143	148	150	163	153	169	**161**	160	117	132	122	79	108	83	106
O	122	142	136	142	121	138	139	145	135	162	144	160	**157**	113	129	132	116	100	88	96	108
Total number of node points = **275**																					
Number of points 300~900 Lux = **57**																					
Number of glare points (>900 Lux) =**11**																					

Table VII: Summery result of illumination condition for different cases

Different Cases	Average Illumination	No. of Point <300 Lux	No. of Point 300-900 Lux	No. of Glare Point (>900 Lux)
Case A	251	215	46	14
Case B	365	183	66	26
Case C	332	187	67	21
Case D	277	207	57	11

4.4 Fluctuations of daylight levels

The Figure 11 shows how the illuminance levels drop to the end points of the studio. In Case A at D13 point the illumination was 454 Lux which raised to 1249 Lux in Case D, whereas the last end of the room point O13 was 92 Lux and it increased to156 Lux in the following case.

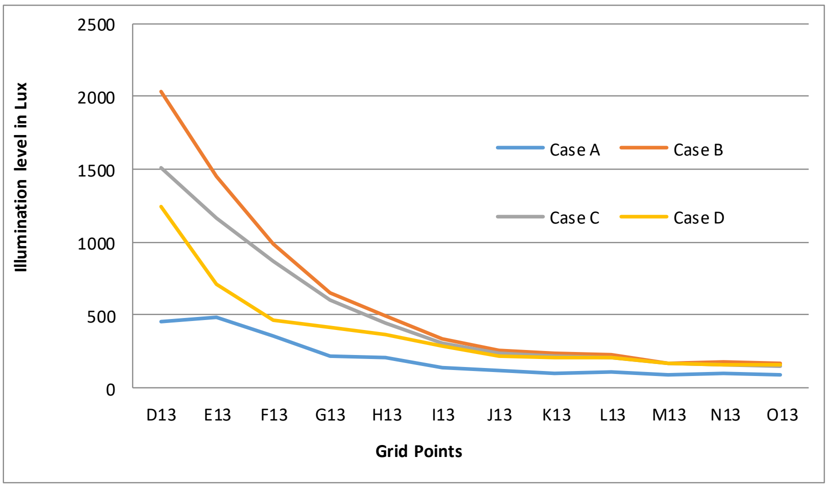


Fig. 11: Drop of light along XX' axis for four different cases

4.5 Comparison of rendered images

A 3d realistic view of four cases (Figure 12) get from the RADIANCE rendered image. Contour lines of daylight distribution give the notion how the light transmits to the whole study area.

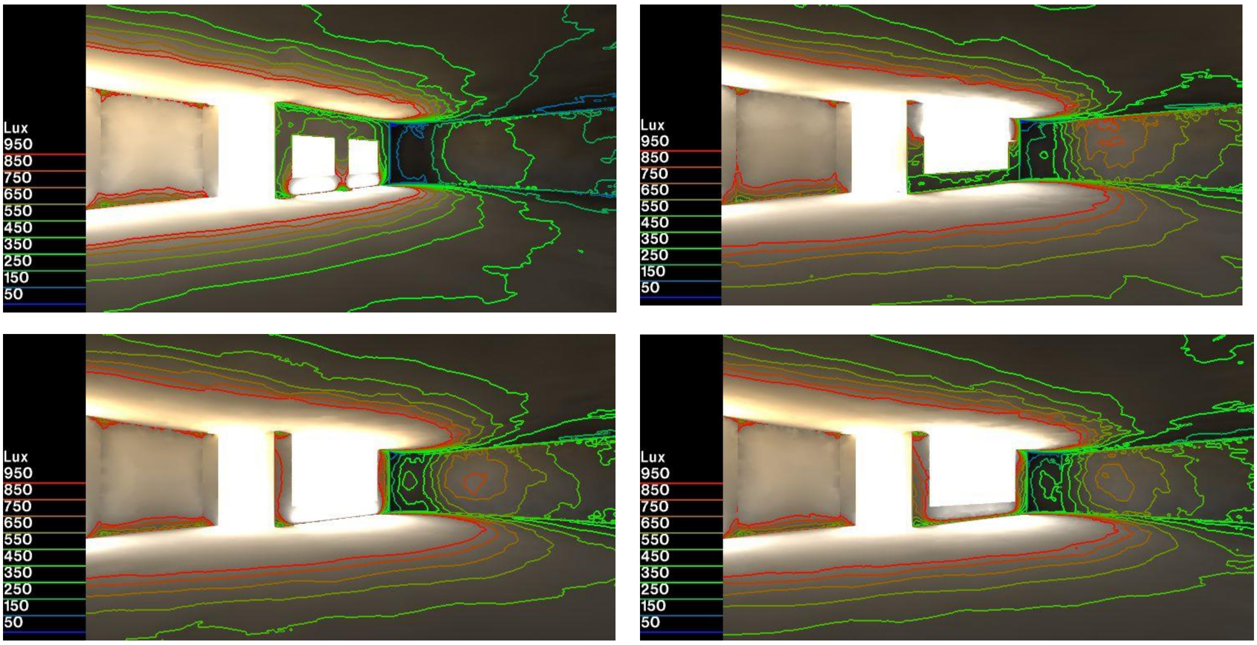


Fig. 12: Daylight contour distributions in different design cases A to D clockwise

4.6 Performance metrics

For four different Cases of window configuration, daylight factor (DF), conventional daylight autonomy (DA), continuous daylight autonomy (DAcon), and useful daylight index (UDI) were calculated. For all performance metrics, the same annual illuminance profiles were used based on DAYSIM calculations. Table VIII shows the different performance metrics in DAYSIM simulation for each Case.

Table VIII: DAYSIM simulation results for different steps

Design steps	DF ≥ 2%	DA %	DAcon > 80%	DAmax > 5%	UDI < 100	UDI 100-2000	UDI > 2000
Step A	43%	1%-99%	93%	29%	53%	0%	47%
Step B	70%	25%-99%	99%	46%	17%	0%	83%
Step C	65%	20%-99%	99%	43%	19%	0%	81%
Step D	68%	18%-99%	99%	40%	19%	0%	81%

Comparing the annual performance metrics for four cases, it is found that the DA, DAcon above 80% and case B, C, D is greater than case A. According to DF Case B is better than other again it will be better if we consider DAmax. But if we analysis UDI levels it is clear that Case C and Case D is best situation.

The simulation results are also shows that the existing situation is not suitable for students because most of the part of the studio does not get light. But only widen the window will increase the glare problem though it brings light to most of the part of studio. Again, if shading and light shelf is used this situation will be better. And the figure 12 shows the step D is the best solution when both inner and outer light shelve has used as the glare is lowest. So, in step D the situation is more preferable as the overall distribution of light is even though the average illumination is low.

5. CONCLUSION

The people of Bangladesh are less aware of daylight use and the benefits of it. Even they have very little knowledge about the negative impact of the absence of natural light. Simultaneously, they are barely informed about the simulation process. Through the study, they can know that any design decision can be taken during the design phase for a better environment of the project. Again, the study opens up different ways to research further aspects related to daylight. By studying more parameters of window configurations and conducting a more critical analysis, a best case can be found and implemented for the studios of DUET.

ACKNOWLEDGMENT

We acknowledge Dept. of Architecture, DUET for conducting the physical survey in their studio, the drawings and technical support.

REFERENCES

[1] F. Ahsan, and M. A. R. Joarder, “Effective width of light shelf for daylighting classrooms considering different seasons and sky conditions of Dhaka”, Proceedings of the 2017 International Conference on Green Architecture (ICGrA), Dhaka, Bangladesh, pp.163-170, 2 017.

[2] F. Ahsan, “Investigation Of Adjustable Lightshelf For Daylighting Classrooms Considering Different Sky Conditions Of Dhaka,” (Unpublished M. Arch thesis), BUET, Dhaka, Bangladesh, 2019.

[3] R. S. Ulrich, C. Zimring, A. Joseph, X. Quan, & R. Choudhary, “The role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity”, Concord, CA: The Center for Health Design, 2004.

[4] P. Boyce, C. Hunter, & O. Howlett, “The benefits of daylight through windows”, Troy, NY: Rensselaer Polytechnic Institute, 2003.

[5] C. J. Kibert, “Sustainable construction; Green building design and delivery,” 2nd ed. New Jersey: John Wiley & Sons, Inc., 2008.

[6] N. Baker and K. Steemers, Daylight design of buildings, Earthscan/James & James, 2002.

[7] J.A. Veitch, “Principles of Healthy Lighting: A Role for Daylight,” National Research Council Canada (NRCC). Report no. NRCC-46758. Canada. P2, 2003.

[8] U.S. Department of Energy’s Office of Building Technology, State and Community Programs Report, “Energy-Smart Building Choices: How School Administrators & Board Members Are Improving Learning and Saving Money,” 2002.

[9] Environmental Monitoring Report, 2016 Local Government Engineering Department, April 2016.

[10] J. Santamaria, & C. Bennett, “Performance effects of daylight,” Lighting Design and Application, 11, 31–34, 1981.

[11] P. Tregenza, and M. Wilson, “Daylight coefficients and numerical models,” Daylighting: architecture and lighting design. New York, NY: Routledge, 2011.

[12] M.A.R. Joarder, Z.N. Ahmed, A.D.F. Price, and M.M. Mourshed, “A simulation assessment of the height of light shelves to enhance daylighting quality in tropical office buildings under overcast sky conditions in Dhaka,” Bangladesh. Eleventh International IBPSA Conference, (Building Simulation 2009), 27-30 July, Glasgow, Scotland, pp.920-927, 2009.

[13] D. Prowler, FAIA, Donald Prowler and Associates Revised and expanded by Joseph Bourg, Millennium Energy LLC Last updated: 12-18-2014

[14] A. G. S. 2000, Architectural Graphic Standards, John Wiley & Sons, Inc. New York, CD Rom Versions, 2000.

[15] BNBC. 2006. Bangladesh National Building Codes, Housing and Building Research Institute and Bangladesh Standards and Testing Institute, Dhaka, 2006

[16] Illuminating Engineering Society of North America (2000). The IESNA Lighting Handbook: Reference and Application. Ninth Edition. IESNA Publication Department. USA. pp. 335, 2000

[17] N. Iqbal, Incorporation of Useful Daylight in Luminous Environment of RMG Factories by Effective use of Skylights in Context of Dhaka. (Unpublished M. Arch thesis), BUET, Dhaka, Bangladesh, 2015.

[18] D.B. Crawley, J.W. Hand, M. Kummert, and B.T. Griffith, “Contrasting the Capabilities of Building Energy Performance Simulation Programs” Joint Report Version 1.0. International Building Performance Simulation Association, Montreal, August 15 – 18, 2005.

[19] E.E. Osaji, and A.D.F. Price, “The Role of Parametric Modelling and Environmental Simulation in Stimulating Innovation in Healthcare Building Design and Performance,” HaCIRIC 2nd International Conference, April, pp. 135-44, 2009.

[20] N. Baker, A. Fanchiotti, K. Steemers, Daylighting in Architecture. James & James Science Publishers Ltd; 1993:2.7, 2. 8, 2.10, 2002.

[21] C.F. Reinhart, J. Mardaljevic, and Z. Rogers, “Dynamic Daylight Performance Metrics for Sustainable Building Design. Leukos,” 3(1). pp. 7–31, 2006.

[23] P.J. Littlefare, “Designing With Innovative Daylighting. Building Research Establishment report,” Herts: Construction research Communications, 1996.

[24] J.R. Goulding, J. O. Lewis, T. C. Steemers, “Energy Conscious Design: A Primer for Architects,” London, Batsford for the European Commission, 1992.